I. Generator-Related Outdoor CO Poisonings on Houseboats - 1

■ CO-Related Fatality ‣ Non-Fatal CO Poisoning

Silver Glen Springs near Ocala, Florida

■On August 24, 1995, a man wearing snorkel gear went into the airspace beneath the extended rear deck of a 1994 Stardust houseboat to check the engine outdrive. The boat's 12.5 kW Kohler generator was activated just before he entered the airspace. The generator exhaust terminus was directed into the airspace. The boat propulsion engines were not operating. Approximately 5 minutes after he entered the airspace, he was observed floating unresponsively face down in the shallow water. He was retrieved from the water and bystanders administered CPR. He was then transported to shore, and Emergency Medical Service was called. He was resuscitated in the hospital emergency department, and but died 17 hours after his exposure. His COHb (carboxyhemoglobin – CO in the blood) measured in the hospital 2 hours after exposure, and after more than an hour on oxygen therapy, was 29.7%. A forensic toxicologist estimated that the man's COHb was greater than 70% when he collapsed. Inspection and testing of the houseboat revealed that operation of the generator caused rapid accumulation of CO in the above-water airspace beneath the deck (the airspace he entered) such that the concentration would reach 4,000 to 10,000 ppm within 2 to 5 minutes after the generator was activated. The cause of death determined by autopsy was cerebral anoxia, due to acute carbon monoxide poisoning with submersion. The lawsuit related to this case was reportedly settled out of court. (Source, Lab Director, Miami-Dade County Medical Examiner Department) **– Rear-directed generator exhaust terminus**

Table Rock Lake, Missouri

‣ In the summer of 1999, two girls swimming behind a houseboat succumbed to generator exhaust, but were rescued in time. (Source: Kansas City Star, 12/14/00, Lee Hill Kavanaugh). Records related to this incident revealed that the children were aged 8 and 11, and were found unconscious floating behind the Gibson 54' houseboat. One of the girls was not breathing when she was found. The girls had been wearing personal flotation devices swimming behind the boat as the boat owner worked on the front of the boat. The generator (no manufacturer specified) was operating at the time, and the exhaust of the generator "comes out of the boat right under the swim platform where they were swimming." (Source: Missouri Department of Public Safety, Missouri State Water Patrol Accident Investigation Report) **– Rear-directed generator exhaust terminus**

I. Generator-Related Outdoor CO Poisonings on Houseboats – 2

■ CO-Related Fatality ‣ Non-Fatal CO Poisoning

Lake Havasu, Arizona

■■A past general manager of 3 Buoys Houseboat Vacations reported the following information: The company was based in Canada, but had 11 marinas in the US. One of the marinas was on Lake Havasu, where they had 75 boats that were time share/rentals (several owners, but also rented to non-owners). Their boats were 54' long, 14'wide, with generators that exhausted under the rear deck at water level. In 1985, the company was sued because two employees died from CO exposure while sitting on the rear swim platform when the generator operated. The company settled out of court on that case. They installed CO detectors on the rear deck, up high near the door, and elsewhere in the boats. The following year, two customers were poisoned in the same circumstance - sitting on the rear deck platform. (In this second instance, the boat was 4-5 miles from the lake on the river.) (Source: Personal communication, Past Manager of the Houseboat Rental Company) **– Rear-directed generator exhaust terminus**

Lake of the Ozarks, Missouri

‣ In June 1998, a 4-year-old girl was swimming behind the stern deck of a Gibson houseboat with a group of other children. She wearing a personal flotation device, and was under the direct supervision of adult swimmers. After she swam to the swim platform, holding on to the ladder while her mother applied sunscreen to her face, she swam away. Within moments she was observed floating face up on the water, unconscious and rigid. She was quickly brought into the boat where her mother, a registered nurse, checked her for respirations and pulse. She appeared pale and stiff at that time, was unresponsive with poor respiratory effort. After 2 to 3 minutes of aggressive stimulation, the child began responding with grunts but was described as disoriented and sleepy. While her mother continued rescue efforts, her father called for emergency medical services. Paramedics arrived in 10 to 15 minutes, administered oxygen, and transported the child to the nearest hospital emergency department within 30-45 minutes. Her venous COHb level at the hospital after approximately 1 hour of oxygen therapy was 22.2% (with a listed normal range of 0.1 to 2.0%). Upon examining the houseboat during their next visit to the lake, the child's parents discovered that the exhaust terminus for the onboard generator that was operating at the time of this poisoning was located at the edge of the swim platform, in the center of the rungs of the ladder that the child was holding onto when the sunsreen was applied. (Multiple sources including the parents and a peer-reviewed publication) **– Rear-directed generator exhaust terminus**

■In the summer of 1999, a man died on this lake as he swam behind a houseboat. An autopsy revealed that death came not from drowning, but by asphyxiation from CO. We currently have no further information on this death. (Source: Kansas City Star, 12/14/00, Lee Hill Kavanaugh) **– Unspecified generator exhaust location**

I. Generator-Related Outdoor CO Poisonings on Houseboats – 3

■ CO-Related Fatality ‣ Non-Fatal CO Poisoning

Lake Travis, Texas

‣ A 19-year-old employee of a houseboat rental company was piloting a 66' houseboat (no manufacturer specified) when a buoy cable became entangled in the engine propeller. After deactivating the generator (the exhaust of which was directed to the rear of the boat into the airspace beneath the swim deck) and waiting a few minutes to assess the situation, he decided to go under the aft swim deck of the boat to free the cable. He was aware of the carbon monoxide (CO) danger and made efforts to avoid breathing while under the swim deck. Unable to hold his breath long enough, he was forced to take two breaths while working to free the cable. A coworker arrived on the scene minutes later to find the employee unconscious. The employee was airlifted to the nearest hospital. Doctors later reported that his blood carbon monoxide level was in the lethal range, although no specific details were available from the reporter of this incident. (Source: Personal communication from the rental company manager, Austin TX) **- Rear-directed generator exhaust terminus**

‣ Upon reading the press coverage of the poisonings at Lake Powell, the manager of a fleet of 9 large rental houseboats phoned to say "We've been waiting for this day for years." Between 1995 and 2000, he had personal involvement with four documentable cases of aft swim-deck CO poisonings (including the one above) and indirect knowledge of numerous others. None were fatalities, but two required hyperbaric oxygen treatment. All involved generator exhaust routed under the swim deck at the back of the boat. At least one of the poisonings was reported to have occurred when the occupant entered the airspace under the swim deck 10-12 hours after boat engines and generator had been deactivated. The manager stated, "I know of no incidents from houseboats with side exhaust." (Source: Personal communication from the rental company manager, Austin TX) **– Rear-directed generator exhaust terminus**

Center Hill Lake, Tennessee

■■ In May 1997, a father dove under his houseboat to fix a mechanical problem. Because the father did not surface, his son dove under the boat to find him. Both men died of CO poisoning. We currently have no other details. (Source: Arizona Republic, November 29, 2000) **– Unspecified generator exhaust location**

I. Generator-Related Outdoor CO Poisonings on Houseboats – 4

■ CO-Related Fatality ‣ Non-Fatal CO Poisoning

Tims Ford Lake, Tennessee

■A 61-year-old woman cleaning algae from the back of a houseboat in Tennessee died from CO exposure in June 2000. Her husband dove into the water to save her and began to experience symptoms of CO poisoning as well. Overwhelmed by the gas, he tied his wife's hands to the boat to keep her afloat until rescuers arrive. His wife died of CO poisoning. "It just overwhelmed her." (Source: Arizona Republic, November 29, 2000; also AP, Scott Thomsen, December 25, 2000, "Doctor Homes in on Monoxide Threat") - **Unspecified generator exhaust terminus location**

Dale Hollow Lake, Tennessee

■In 1997, a family rented a houseboat from Hendrick Creek Resort on Dale Hollow Lake. Several children were playing on the slide and around the back of the boat all day while the generator operated to power the air conditioning inside the boat. One of the children reported to her mother three times that day that she felt sick, but her symptoms were attributed to the hot weather and sun. Her mother had also been feeling ill when she sat in a tube tied to the back deck of the houseboat, and attributed her symptoms to the exhaust, but not necessarily to CO. The mother had the child go in and lie down for a few hours, and then let her go back out to swim. In the afternoon, the child swam on the side and rear of the boat. The exhaust exited the boat very near the area where she swam. Her 7-year-old brother was on the stern deck playing. He was talking to her and she told him that she felt sick. He told her to get out of the water. She was reaching for the ladder, and did not make it. She sank into water that was 8-11 feet deep. The boy reported to his mother that the girl had gone down and didn't come back up. The child's body was found by emergency responders. Although an autopsy was performed, no carboxyhemoglobin analysis was done. (Source: E-mail from the child's family) **– Unspecified generator exhaust terminus location**

I. Generator-Related Outdoor CO Poisonings on Houseboats – 5

■ CO-Related Fatality ‣ Non-Fatal CO Poisoning

Lake Mead, Nevada

‣ In July 1997, a man working to clear a rope from around the propellor on a rented houseboat lost consciousness as a result of exposure to CO in generator exhaust. (Source: Review of National Park Service EMS records) **– Unspecified generator exhaust terminus location**

‣ In October 1997, an 8-year-old child floating in a small rubber raft on the starboard side of a houseboat was poisoned by CO in houseboat generator exhaust. He was exposed for about 5 minutes when he became dizzy, and fell down when he tried to walk. He was transported to a local hospital for treatment. (Source: Review of National Park Service EMS records) **– Unspecified generator exhaust terminus location**

‣ In June 1999, a child was playing near a houseboat generator for about 10 minutes when she fell into the water and lost consciousness as a result of CO exposure. (Source: Review of National Park Service EMS records) **– Unspecified generator exhaust terminus location**

II.Generator-Related CO Poisonings Inside Houseboats - 1

■ CO-Related Fatality ‣ **Non-Fatal CO Poisoning**

Lake Cumberland, Kentucky

‣ In June 2000, 15 people, ages ranging from 16 to 47, were overcome by CO on two rented houseboats. One of the houseboats was a 3-month-old 77-foot Stardust. No information was available on the second boat. The boats were tied together and anchored in a cove. Both boats had gasoline-fueled generators. The exhaust of one of the generators seeped into the adjacent boat through an open bathroom window. CO was circulated through the full interior of the boat by the central air-conditioning system. Boat occupants who awoke at about 5 a.m. had headaches and were nauseous. Realizing they had a problem, the group radioed the marina and ambulances met the boats at the shore. The Kentucky Water Patrol Officer that responded to the emergency witnessed that two occupants were unconscious when he arrived, and others were drifting in and out of consciousness. All 15 people were treated at the emergency department of a nearby hospital; three were admitted as hospital inpatients for further treatment. There were six carbon monoxide detectors on this boat, but none were properly connected when the boat was inspected after the poisoning incident. Boat occupants denied unhooking the detectors. The marina's general manager said the detectors should have been working when the boat was manufactured, but no other information was available. (Source: News articles from an unspecified newspaper) **- Side-directed generator exhaust terminus**

Dale Hollow Lake, Kentucky

‣ On April 18th, 2000, 11 people were poisoned inside the houseboat they were occupying. One person lost consciousness, and 9 children experienced vomiting and extreme headaches. They ran the generator during the nights while they slept. They were told at the hospital that this was the second time this year that his had happened at this lake. (Source: Lake-Times News, May 1, 2000; personal communication – e-mails from victims) **– Unspecified generator exhaust terminus location**

The Delta, Stockton California

‣ On June 13th, 1999, on a houseboat anchored in Dredge Cut, 9 people were overcome by carbon monoxide from a propane-powered generator. The responding emergency medical technician and a fellow deputy became poisoned themselves as they worked to diagnose the problem, and evacuate boat occupants. They spent two hours in the emergency room breathing oxygen. No other details were available from the newspaper article covering the incident. (Source: San Francisco Examiner, Saturday Jun 19, 1999) **– Unspecified generator exhaust terminus location**

II. Generator-Related CO Poisonings Inside Houseboats - 1

■ CO-Related Fatality ‣ **Non-Fatal CO Poisoning**

Laurel Lake, Kentucky

‣ Six adults and 11 children were roused in the early morning only when a passenger heard her 20-month-old son vomiting. As the mother tried to get to her son, she could hardly move. Gradually, she arose, wakened the remaining passengers who reported feeling drowsy, sick, and wracked by headaches. All passengers were diagnosed as having CO poisoning, with CO blood levels ranging from 3 to 17 percent. One passenger was hospitalized, and the others were treated with oxygen and released. The victims were on a rented 72-foot houseboat that had a gasoline-powered generator that was operating at the time of the poisonings, and had been operating through out the night. There were no CO detectors on the boat. (Source: Lexington Herald-Leader, Stephen Trimble. Found in an internet search, no date listed on the article.) **– Unspecified generator exhaust terminus location**

Lake Meredith National Recreation Area (US NPS), Texas

■■■On March 11th, 1984, three people died as they slept on a boat docked in the marina. A faulty exhaust manifold on a generator was blamed as the three died of carbon monoxide poisoning. (Source: Amarillo Globe-News, September 4, 1999) **– Unspecified generator exhaust terminus location**

Lake Mead (US NPS), Nevada

‣ In November 1996, a man working on a houseboat "in a confined space for 7 hours" and exposed to "noxious fumes" experienced headache, nausea, vomiting, dizziness, light-headedness, and difficulty walking was assessed as having CO poisoning and transported by air to a local hospital. (Source: Review of NPS EMS records) **– Unspecified generator exhaust terminus**

‣ In October 1997, a woman was asleep in the rear cabin of a houseboat when the CO alarm sounded , awaking her and others on the boat. The woman lapsed into unconsciousness and also suffered from nausea. She was transferred to a hospital for treatment. Records indicated that two houseboats were tied together, and that both boats were operating their generator. (Source: Review of NPS EMS records) **– Unspecified source of CO and unknown generator exhaust terminus location**

‣ In July 2000, occupants of a houseboat were poisoned while sleeping in the rear cabin. The on-board generator was operating at the time of the poisoning. An inspection of the boat indicated that plumbing holes in the floor of the adjacent bathroom allowed CO to enter the sleeping area. In addition, it was also noted that the exhaust for the generator was close to the cabin's rear area. Inspectors suggested that the exhaust be moved closer to the rear of the boat. (Source: Review of NPS EMS records) **– Side-directed generator exhaust terminus**

II. Generator-Related CO Poisonings Inside Houseboats – 2

■ CO-Related Fatality ‣ Non-Fatal CO Poisoning

Table Rock Lake, Missouri

‣ In July 2000, 8 people were poisoned on a houseboat rented from Tri-Lakes Houseboat Rentals. Records related to this incident indicated that the County Fire Department measured "high levels of CO on the stern deck of the boat and in the engine compartment while the generator was running." They also checked inside the passenger area of the boat, and found "levels were higher than normal when the back door of the boat was open." The wiring to the CO detector on board the houseboat had been cut at some point, and the CO detector was not functioning at the time of this incident. The CO detectors were not routinely checked on the boats. It is not clear from this report where the poisoned occupants were when the onset of symptoms occurred. It is assumed that some of the victims were on the stern deck because the report refers to measurements in that area. However, the number of people poisoned indicates that the exposure may have occurred inside the boat. (Source: Missouri Department of Public Safety, Missouri State Water Patrol Accident Investigation Report) **– Unspecified generator exhaust terminus**

III. OUTDOOR CO POISONINGS ON BOATS *OTHER THAN HOUSEBOATS*

Lake Sylvan, Ohio

In August 2000, an 11-year-old girl was riding on the swim platform of a 21' inboard Malibu ski boat with two friends who were near her age. The boat was moving slowly (operating under 10 miles per hour) while the children lay on their stomachs on platform with their legs dangling in the water. The weather was calm and clear. The girl began to lose consciousness, falling from the boat, grabbing the ankle of the child next to her as she went. The third child on the platform dove into the water to try and save the other two, as did another boat passenger. The 11-year-old girl disappeared from view and drowned. Her autopsy carbon monoxide blood concentration (carboxyhemoglobin – COHb) was 50%. (Source: Personal communication, Investigation and autopsy lab report forwarded to Dr. Baron by Duane Lucas, Ohio Division of Water Craft)

St. John's River, Florida

In May, 2000 an 8-year-old boy died from CO poisoning while he was on or near the swim platform of a 1997 pleasure motor boat. The boat was anchored in the river, and the onboard generator was operating, with exhaust discharging to the rear of the boat in close proximity to the platform where the boy was positioned. The boy disappeared from the platform. His body was later found in the water. The autopsy revealed that the boy's carbon monoxide blood concentration was 34.8%. (Source: Law firm representing the family of the boy.)

Unspecified water body, New York State

A 16-year-old girl bathing off the stern of a recreation open bow motor boat (1981 Crestliner 17' pleasure craft) died from CO poisoning. The boat was in the center of a freshwater lake. The boat engine was operating because the girl's swimming partner had asked other boat occupants to activate it to warm the water where they were swimming behind the boat. After swimming for approximately 10 minutes her partner felt tired and cold and got back into the boat. As he looked back at the girl still in the water, he noticed that she put her head in the water, and then disappeared. He thought she was taking an underwater dive, but became alarmed when she didn't resurface. Her body was found five days later, 50-feet deep in the water. The autopsy revealed a carbon monoxide blood concentration of 62%. Testing of the boat conducted after the death revealed that CO was present in concentrations of 100 ppm in the air several inches above the water level at the stern when the engine idled for 8 minutes. The largest accumulation of CO was at the stern just above water surface as well as at the transom. (Source: Peer-reviewed publication – Jumbelic MI [1997]. Open air carbon monoxide poisoning.]

Lake Mead, Nevada

A child lying on a personal water craft with her face next to the exhaust port was poisoned as the craft moved across the water. She lost consciousness and was unable to repond to EMS personnel. She recovered after treatment with oxygen, and was transported to a local hospital. (Source: Review of NPS EMS records)

IV.Generator-Related CO Poisonings Inside Cabin Cruisers

Lake of the Ozarks, Missouri

■■■■ In June 1999, four people died as a result of CO exposure inside a 40' Silverton Cabin Cruiser that was tied to a dock. The victims had gone to the lake to spend Memorial Day weekend on the boat. When they had not returned by Tuesday afternoon, relatives contacted authorities to report them missing. A Water Patrol officer found the boat docked at a restaurant, where it was reported to have been docked since Sunday. Lights inside the houseboat were operating and the generator was running. A 40-year-old man, and two friends, aged 32 and 42, were found dead inside the boat. The man's 39-year-old wife was observed to be breathing when emergency responders arrived, but died shortly thereafter. The cause of death was carbon monoxide poisoning resulting from a rusted generator exhaust pipe that allowed CO to leak into the cabin of the boat. The local fire department measured 272 parts per million of CO inside the cabin door of the cruiser after the victims had been removed from the boat cabin. (Source: Several, including news clips forwarded by Scott Thomsen, AP; News coverage from the Jefferson City News Tribute, Wednesday June 2, 1999; pieces from the internet) . (Also: Missouri Department of Public Safety, Missouri State Water Patrol Incident Report Number F99-3410) **– Unspecified generator exhaust terminus location**

Laurel Lake, Kentucky

‣ In August 1998, six people were overcome by carbon monoxide and transported by ambulance to Lake Ozark General Hospital for treatment. The operator of the boat advised investigators that the 36' Carver Cabin Cruiser boat was headed for Bridal Cave where two of the passengers were to be married. The door to the cabin was open while the boat was en route. This allowed CO to enter the cabin area. (Source: Missouri Department of Public Safety, Missouri State Water Patrol Incident Report Number H98-3710) **– Unspecified generator exhaust terminus location**

Lake Norman, North Carolina

‣ Six boaters became ill from CO that leaked into the cabin of a 36-foot boat docked at a restaurant. The boat's onboard generator was operating to power the boat air conditioner. Four adults and two girls, aged 8 and 9, were treated for CO poisonings at Carolinas Medical Center and Presbytarian Hospital. (Source: News clips forwarded by Scott Thomsen, AP) **– Unspecified generator exhaust terminus location**

IV.Generator-Related CO Poisonings Inside Cabin Cruisers

Florida

■On June 30, 1995, a man went to check out his boat that was docked at its bulkhead. He activated the boat's air conditioner, and left up the canvas and plastic covering that enclosed the top deck. A few hours later, he was found dead from CO poisoning. The boat's engines, generator, and air conditioning system were still operating and the boat's CO alarm was sounding. Exhaust from the boat's engines coming in through the rear entry flap of the boat's deck covering had killed him. Testing of the CO alarm indicated that the alarm was miscalibrated and did not go off until almost an hour after it was supposed to. By the time the alarm sounded, the man could no longer help himself. One result of lawsuits related to this case was the discovery that testing conducted by the manufacturer of the CO alarm showed repeated malfunctions of the alarms. Changes in the manufacturing process had allowed contamination of sensitive components of the alarm. This alarm used a sensor similar to the one in the First Alert CO alarm. According to the manufacturer, the alarm sensor mimics the body's carboxyhemoglobin level over a period of time. There had been a longstanding problem with other gases and fumes contaminating the sensor during the manufacturing process. This would cause the sensor to "drift", which in turn results in miscalibration of the sensor, and faulty alarming. The following information is included in the court's decision:

"The United States Coast Guard and a well-known boating industry organization, the American Boat and Yacht Council (ABYC) went to great lengths to try and educate the boating industry to the potential for carbon monoxide poisoning. For several years prior to the manufacture of this boat, the ABYC developed a recommended standard that went into effect shortly after the decedent's boat was manufactured. However, this recommended standard was widely circulated within the boating industry well prior to the construction of decedent's boat. Further, [the boat manufacturer] did absolutely no scientific testing to determine if and how carbon monoxide would enter into its boats after they had been constructed. The closest testing that [the boat manufacturer] did consisted of a "sniff" test performed by its primary boat designer and its boat tester, both of whom were very "sensitive" to carbon monoxide."

Other problems were that the CO alarm was installed in an area of the boat cabin contrary to instructions in the alarm manual, was wired directly to the boat batteries which caused the batteries to fail. Further, there were no instructions or warnings given to the decedent about operating conditions in which he would be exposed to hazardous levels of CO. The settlement for this case was $3,000,000 for the wife of the victim. (Source: Pajcic and Pajcic "Profiles and Precedents" biannual report of settlements for the last six months of 1997; and Florida Jury Verdict Reporter, a publication of Florida Legal Periodicals, Inc., Volume XVIII, No. 10, Oct 1997)) **– Unspecified generator exhaust terminus location**

Lake Mead (US NPS), Nevada

■ ‣ In May 1993, two people were poisoned (one died and one survived) while they slept in the cabin of an anchored (at shore) 25' 1981 Searay Cabin Cruiser. The source of CO was an on-board gasoline-powered generator. No loose fittings or leaks were found. (Source: Review of NPS EMS records) **– Rear-directed generator exhaust terminus**